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AEROJET-GENERAL CORPORATION

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VON KARMAN CENTER

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3 June 1964

Subject: Informal Monthly Report on the Investigation of Stress Corrosion Cracking of High Strength Steels for the Month of April 1964. Report LO414-02-7

To: Commanding Officer
Frankfort Arsenal
Philadelphia, Pennsylvania

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Reference: Contract DA-04-495-ORD-3069, Modification No. 4

This is the thirty-first in a series of informal progress reports submitted in partial fulfillment of the contract. It constitutes the seventh monthly report on the second one-year continuation of the original two-year program. It was written by R. B. Setterlund who was supervised by A. Rubin.

I. OBJECTIVES

A. To study the stress-corrosion characteristics of 18% nickel maraging steel with respect to compositional variation.

B. To study the effect of environmental temperature on the rate of stress-corrosion cracking in three alloys: 18% nickel maraging steel, a low-alloy martensitic steel, and a hot-worked die steel.

C. To study the electropotential changes occurring in 18%-nickel maraging steel during stress-corrosion exposure, and the effect of applied potential.

II. WORK PROGRESS

A. COMPOSITIONAL VARIATION

In order to study the effects of compositional variation, four heats of 18% nickel maraging steel were obtained from three vendors. It was felt that these four heats, in conjunction with the heats previously tested, represent the compositional range of material under present commercial production.

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Particular attention is centered around the 250 ksi yield strength level, where the 18% nickel maraging steel appears to have the greatest utility. The chemical analysis of these materials are shown in Table 1, group b, and the mechanical properties in Table 2, group b.

These four heats along with conventional alloys, group c, Tables 1 and 2, are being tested in the three environments that caused the most rapid failures in the previous years' work. These are: (1) aerated distilled water, (2) aerated 3% NaCl solution, and (3) 140°F water-saturated air. Three replicate tests are being conducted for each test condition, using beam specimen stressed elastically to 75% of the yield strength, as well as plastically deformed U-bend specimens. These tests are nearly complete as shown in Table 3. Basically our tests have shown:

1. Stress corrosion susceptibility of maraging steel increases with strength level; however, even the lowest strength alloy tested (181 ksi yield) failed when tested in a U-bend configuration in ambient water environments.
2. Complete immunity to failure can be obtained with the conventional martensitic steels by employing a sufficiently high tempering temperature.
3. The addition of 3% NaCl to distilled water lessens the susceptibility of the test alloys to stress corrosion failure. This trend was most noticeable with the DCAG material.

B. ENVIRONMENTAL TEMPERATURE

In order to assess the effects of environmental temperature, bent beam and U-bend specimens were tested in distilled water environments controlled to 120 and 160°F. All specimens ~~in both environments have failed~~ except for the low alloy steel tempered at 1100°F. Environmental temperature was found to have a great effect on the failure time of maraging steel with the susceptibility doubling for every 18°F increase in temperature. ~~The conventional high strength steels were found to be little effected by temperature.~~

Table 3 shows the overall status of tasks A and B. Individual failure times were shown in the previous Quarterly Report and final results will be detailed in the next report, which will constitute the final summary report.

C. ELECTROPOTENTIAL CHANGES

Two individual experiments are being conducted to study the electro-potential changes and the effect of applied potential in 18% nickel maraging steel in order to understand the mechanism involved in stress corrosion cracking.

1. Utilizing a center cracked specimen, the effect of applied stress on crack tip corrosion potential was determined. The potential of 18% nickel steel was found to become 0.0175 mv less noble for every 1000 psi net stress.

2. Utilizing 20% nickel maraging steel bent in a U-bend configuration, the effect of applied constant potential on stress corrosion in a 5% NaCl solution was determined. The results are shown tabulated below:

<u>Volts to</u> <u>Saturated Calomel Cell</u>	<u>Initial</u> <u>Current Density</u> <u>(MA/in.²)</u>	<u>Failure Time</u> <u>(hr)</u>
-0.95	-3.6	2.1
-0.86	-2.0	no failure (168 hr)
-0.39	-0.5	1.2
-0.36	-0.4	2.1
-	none	1.9 and 2.8
-0.15	+4.0	2.1

Handwritten note: An arrow points from the -0.86 V row to the -0.15 V row, with the text "F₁₂ p 2" written next to it.

~~These tests show that~~ by application of the proper amount of cathodic current, stress corrosion cracking of maraging steel may be stopped. However, if the current is increased over this critical amount, no protection is furnished. ~~These tests are continuing.~~

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Handwritten signature: U. L. Brelant
Dr. S. Brelant, Manager
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TABLE 1
MILL-CERTIFIED CHEMICAL ANALYSIS OF PROGRAM MATERIALS

Supplier	Heat No.	Composition, %														
		C	Mn	P	S	Si	Ni	Co	Mo	Al	Cr	Zr	Ti	Ca	B	N
(a) Maraging Steel from Previous Program																
Republic Steel	3960302	0.02	0.08	0.007	0.006	0.15	18.48	7.00	4.84	0.21	0.10	0.035	0.50	-	0.0036	-
Allegheny-Ludlum	448	0.029	0.002	0.004	0.008	0.009	18.51	8.48	4.92	0.089	-	-	0.52	-	-	-
Allegheny-Ludlum	V-24172	0.012	0.01	0.003	0.003	0.01	18.69	8.90	4.92	0.029	-	0.003	0.62	0.006	0.002	-
Allegheny-Ludlum	476	0.02	0.08	0.006	0.003	0.014	18.60	9.03	4.90	0.078	-	-	1.00	-	-	-
Allegheny-Ludlum	V-24254	0.009	0.09	0.002	0.003	0.06	20.41	-	-	0.29	-	0.002	1.40	0.004	0.003	-
(b) Maraging Steel for Present Program																
Republic Steel	3960323	0.029	0.06	0.005	0.006	0.03	17.79	8.90	3.48	0.13	-	-	0.23	-	-	-
Vanadium Alloys	07868	0.02	0.09	0.004	0.003	0.10	17.75	7.60	4.60	0.08	-	0.017	0.52	0.03	0.004	-
Latrobe Steel	C56858	0.03	0.03	0.004	0.008	0.03	18.54	8.00	4.75	0.11	-	0.03	0.49	-	0.004	-
Vanadium Alloys	07868	0.03	0.03	0.004	0.006	0.04	18.54	9.06	4.88	0.09	-	0.088	0.55	0.02	0.003	-
(c) Conventional High-Strength Steels																
Vanadium Alloys	07904	0.38	0.21	0.010	0.008	0.92	-	-	1.33	-	4.75	-	-	-	-	0.51
Allegheny-Ludlum	V-23217	0.495	0.62	0.009	0.003	0.20	0.37	-	0.94	-	1.00	-	-	-	-	0.03

* Some material from previous program will be used to obtain supplementary data.

TABLE 2
MECHANICAL PROPERTIES OF PROGRAM MATERIALS
(AEROJET DATA)

Code No.	Supplier	Heat No.	Heat Treatment		0.2% Offset Yield Strength	Ultimate Tensile Strength	Elongation	Reduction in Area	Rock Hardness	Charpy Impact Energy (ft.-lb./in. ²)
			Hours	Temp						
(a) Maraging Steel From Previous Program										
I-4	Republic Steel	3960502	3	900F	245.3	254.7	4.0	37.0	50.5	570.0
I-6	Allegheeny-Ludlum	448**	3	↓	255.4	265.9	5.0	9.0	52.0	534.0
I-1	↓	W-24178***	3	↓	283.0	294.0	8.0	38.0	53.5	552.0
I-8	↓	476**	3	900F	323.3	330.0	2.5	27.0	56.0	402.0
H-1	Allegheeny-Ludlum	W-24254	4	850F	291.3	302.2	3.0	17.0	54.0	58.3
(b) Maraging Steel for Present Program										
K	Republic Steel	3960523	3	900F	181.5	190.7	5.0	43.0	42.0	538.0
L	Vanadium Alloys	07868	3	↓	248.2	248.2	4.0	-	49.0	592.0
M	Latrobe Steel	056858	3	↓	269.7	275.7	5.0	34.0	51.5	540.0
N	Vanadium Alloys	07268	3	900F	279.1	288.1	4.0	18.0	52.0	560.0
(c) Conventional High Strength Steels										
A-4	Vanadium Alloys	07914	4+4	1075F	219.2	257.7	7.0	44	49	-
A-3	↓	↓	↓	1025F	232.6	284.8	6.0	42	52.5	-
A-2	↓	↓	↓	975F	223.5	280.6	6.5	43	53	45.4
A-1	Vanadium Alloys	07914	4+4	940F	222.2	292.4	7.0	44	54	32.9
B-4	Allegheeny-Ludlum	W-23217	2	1100F	203.1	218.5	11	46	44	563
B-3	↓	↓	2	900F	204.6	226.4	7.5	43.5	44	385
B-2	↓	↓	2	800F	214.5	241.2	7	38	45.5	323
B-1	Allegheeny-Ludlum	W-23217	2	600F	237.4	281.3	6	25	51.5	182

* Some material from previous program will be used to obtain supplementary data.

** 200 lb laboratory heats.

*** Received 50% cold reduced, annealed 1 hr 1500°F.

TABLE 3

STATUS OF STRESS CORROSION TESTING

Material Condition (Table 2 Code Numbers)																	
Bent Beam Tests	H-1	I-4	I-6	I-1	I-8	K	L	M	N	A-1	A-2	A-3	A-4	B-1	B-2	B-3	B-4
Aerated Distilled Water	A	A	N	A	A	(N)	A	A	A	A	A	A	A	A	A	A	A
Aerated Salt Water	A	A	N	A	A	(N)	(N)	A	A	A	A	A	A	(P)	(P)	(N)	(N)
120F Distilled Water	-	A	-	A	A	A	A	A	A	A	A	A	A	A	A	-	(N)
140F Saturated Air	A	A	A	A	A	A	A	A	A	A	A	A	(N)	A	A	A	(N)
160F Distilled Water	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	(N)
U-Bend Tests																	
Aerated Distilled Water	A	A	-	-	-	A	A	A	(P)*	A	A	A	A	A	A	A	(N)
Aerated Salt Water	A	-	-	-	-	(P)	A	A	A	A	A	A	A	A	A	(P)	(N)
120F Distilled Water	A	A	-	-	-	A	A	A	A	A	A	A	A	A	A	-	(N)
140F Saturated Air	-	A	-	-	-	A	A	A	A	A	A	A	A	A	A	A	(N)
160F Distilled Water	A	A	-	-	-	A	A	A	A	A	A	A	A	A	A	A	(N)

Code

- A - All samples have failed.
 P - Some have failed, some have not.
 N - No failures to date.
 () - Material presently in test.
 - - No test planned.
 * - Single maverick specimen; two of group of three have failed much earlier.